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ENERGY EFFICIENT RETROFIT

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MANITOBA/CANADA CONSERVATION

AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

The availability of secure and affordable energy supplies is a subject of national concern. It is an accepted fact that our primary energy sources - oil and natural gas - are becoming less accessible and more costly. However, Canada is well-endowed with non-renewable and alternative resources that can provide a bridge into the future.

To this end, the governments of Manitoba and Canada have entered into a Conservation and Renewable Energy Demonstration Agreement which was signed May 9, 1980 and terminates March 31, 1984. The Agreement is dedicated to the development and demonstration of conservation and renewable energy technologies. Equally cost-shared by the provincial and federal governments the program has a total budget of $18 million.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.

- To develop broad public awareness of the potential of renewable energy and conservation technology.

- To provide opportunities for the commercial application of the technologies within Manitoba.

- To create economic spin-off benefits for manufacturing, industry and commerce.

- To create employment in new or existing energy-related industries.

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EXECUTIVE SUMMARY

This project received joint funding under the Manitoba/Canada Conservation and Renewable Energy Demonstration Agreement (CREDA).

The purpose was to study the application of modern energy conservation techniques to an older energy inefficient home.

Bruce Laing of Sunshine Country Construction Company renovated and expanded his home, from 87.2 square meters to 258 square meters of heated living space. Several of the energy efficient features incorporated into the upgrade were: double wall construction, increased insulation, continuous air vapour barrier, triple glazed windows with maximum glazing on the south side, and an air-to-air heat exchanger for ventilation.

Air leakage testing of the renovated house showed a leakage rate of 1.64 air changes per hour at 50 Pascals pressure differential. This is in the range of other low energy homes.

Preliminary analysis of post-retrofit fuel consumption indicated that the normalized annual heating load was reduced by 50%, even though the living area has been nearly tripled. On a unit area basis, the heat load was reduced by approximately 80%, from 256 kW.h/sq. m./year to 43 kW.h/sq. m./year.

An accurate economic analysis of the energy saving retrofit could not be made due to the complicating effect of the simultaneous expansion. However, estimates which compensate for the expansion are included. These show that simple payback is achievable within a range of about 10 to 21 years, depending on the size and pre-retrofit condition of a house.

RÉSUMÉ ADMINISTRATIF

Ce projet a été financé conjointment par le Canada et le Manitoba dans le cadre de l'entente fédérale-provinciale de démonstration des énergies renouvelables et des économies d'energie (DEREE).

Cette étude avait pour but de démontrer l'application des techniques modernes de conservation d'énergie sur une maison moins récente à haute consommation énérgetique.

Bruce Laing de la Sunshine County Construction Company a rénové et agrandi sa maison. En effet, la surface habitée et chauffée de sa maison a passé de 87.2 mètres carrés à 258 mètres carrés. Lors de la rénovation de sa maison, il a utilisé plusieurs moyens pour économiser l'énergie: murs à double épaisseur, accroissement de l'isloation, coupe-vapeur et coupe-air permaments, fenêtres à trois épaisseurs, maximum de fenêtres sur la face sud et échangeur thermique pour la ventilation.

Le taux de fuite d'air de la maison rénovée était de 1,64/h sous une pression différentielle de 50 pascals, résultat similaire à celui qu'ont obtenu les autres habitations à faible consommation énérgetique.

Une analyse préliminaire de la consommation de combustible après les travaux revele que les besoins en chauffage etaient reduits de 35% même si la surface habitée avait presque triplé. Exprimés en kilowattheure par mètre carré par année, les besoins de chauffage ont chuté de 370 à 82, soit environ de 78%.

Une analyse exacte de l'économie d'énergie n'a pas été faite car M. Laing a agrandi sa maison tout en utilisant en même temps des procédés d'économie d'énergie. Par contre, des estimations tenant compte de l'agrandissement ont été incluses. Ainsi, il en ressort qu'il faudrait une simple période s'échelonnant de 7 à 16 ans pour récupérer le coût de l'installation énergétique selon la grandeur et l'état de la maison avant les travaux.

2. INTRODUCTION

Bruce Laing of Sunshine Country Construction Co., New Bothwell, Manitoba, received funds for an energy efficient residential retrofit project under the federal/provincial Conservation and Renewable Energy Demonstration Agreement (CREDA).

The purpose of this project was to demonstrate the advantages of retrofitting older homes, particularly rural homes, with energy conservation features. The overall objective of energy efficient retrofitting is to obtain increased comfort at lower heating costs.

3. BUILDING DESCRIPTION

3.1 General

Bruce Laing of Sunshine Country Construction Co. owns the house, situated in New Bothwell, 64 kilometers southwest of Winnipeg.

The energy saving retrofit of the house included features such as improved insulation levels, a continuous air/vapour barrier, upgraded caulking, new triple-glazed windows, and an air to air heat exchanger to reclaim heat from vented air.

3.2 Building Areas

The original structure was a one and one-half storey, three bedroom house with a south orientation. The house had been modified by the addition of an ante-room (sunroom) and a garage, retaining the original 87.2 square meters (939 sq. ft.) of heated living space. The energy saving retrofit discussed in this report was part of a further expansion that enlarged the living space to 258 sq. m. (2,777 sq.ft.), which is almost three times the original area. This was done by adding a two-storey section, enlarging the existing ground floor, converting the existing basement to an office, and enlarging the basement space into the areas beneath the addition and sunroom.

(Appendix A, Figures A1 and A2, include the floor plans for the original and retrofitted house)

3.3 Exterior Walls

The walls of the original building were built with 2 x 4 studs spaced 406 mm (16 inches) apart. During this retrofit a second wall built with 2 x 4 studs spaced 610 mm (24 inches) apart, was anchored to the outside of the original walls, forming a double wall construction 305 mm (12 inches) thick. Also the walls of the addition are of double wall construction with 2 x 4 studs spaced 406 mm (16 inches) apart in the inner wall and 2 x 4 studs spaced 610 mm (24 inches) apart in the outer wall.

The walls of the lower level are finished with 25.4 x 254 mm (1 x 10 inch) vertical cedar siding, while the upper level walls are finished with masonite siding.

3.4 Basement

The original basement was not considered a living space before the retrofit, since it was unheated and not insulated. The old basement walls were made of 20.3 cm (8 inch) concrete. The south and east walls were retrofitted by the addition of 2 x 4 studs on the inside to provide space for batt insulation. These walls were also insulated on the exterior with two inch rigid polystyrene foam board extending 1.22 meters (four feet) to the footings. The west wall (facing the garage) and part of the north wall were insulated with three inch polystyrene foam board on the inside. Part of the original north wall faces into the new basement and therefore no insulation is required.

The new basement walls are built with 2 x 8 pressure treated studs on 40.6 cm (16 inch) centres and are insulated with glass fibre batts. All walls were sealed with 6 mil polyethylene installed behind the inside finish panelling.

The existing basement floor, which consists of a 10.2 cm (4 inch) concrete slab, was left unaltered. The new basement floor is also a 4 inch slab, laid upon 6 mil polyethylene and 5.1 cm (2 inches) of rigid polystyrene insulation.

3.5 Ceiling and Roof

The roof is now supported by "raised heel" trusses which allow for 50.8 cm (20 inches) of glass fibre batt insulation to be installed up to the exterior wall.

Attic ventilation is provided by eave and gable vents.

3.6 Windows and Doors

The original single glazed windows with added storm windows allowed a high heat loss rate. These were removed and triple glazed windows were installed in place. Glazing was maximized on the south side (8.57 sq. m. total area) where solar gain exceeds heat loss. The north side has only one window with an area of 0.46 sq. m. and the combined glass area of the east and west sides is 6.39 sq. m. Total glass area on the latter three sides was minimized to prevent net heat loss.

The south side main entrance leads in from the sunroom which has a total glass area of 6.13 sq. m. This sunroom serves as an airlock, which prevents winds from blowing directly into the house as the door is opened, to reduce air infiltration.

The second floor is cantilevered three feet over the lower level south wall. This provides shading of the ground floor windows in summer, but allows passive solar gain in winter, when the sun is lower in the sky.

Two double glazed garden doors are situated on the north side; one of them is non-operational and serves as a window. The glass area of the two doors is 1.7 sq.m. The owner is considering installing external shutters on these to reduce the heat loss.

3.7 Insulation

The original structure had minimal levels of wood shaving insulation in most of the walls and ceiling. In the retrofit, the double stud walls, the ceiling and the new basement walls were insulated with glass fibre batts. The old basement was insulated as previously described in Section 2.4. The following table indicates the levels of insulation:

Table I

	RSI	R
Above Grade Walls	7.0	40
Old Basement Walls	3.5	20
New Basement Walls	4.9	28
Ceiling	10.6	60

These levels are well above those recommended by the 1978 Manitoba Building Code, which requires RSI 5.8 (R33) in the ceiling, RSI 2.1 (R12) in the walls and RSI 1.2 (R7) extending to 0.61 meters (2 feet) below grade. The retrofit levels are consistent with many super energy efficient houses.

Installing a continuous air/vapour barrier and using extensive caulking reduced the infiltration into the house. In the wall sections, installing 6 mil polyethelene on the outer side of the inside studs allowed wiring and plumbing to be laid in without breaking the air/vapour barrier.

4. HEATING AND VENTILATION

4.1 Heating

The existing natural gas heating system, rated at 125,000 BTU input, was retained in the retrofit. It was believed that a change in rating was unnecessary, as the conservation measures would roughly balance the increase in heated volume.

Five electric baseboard heaters, rated at 500 W each, were installed in the upper level of the addition. These were installed more for the purpose of improving heat distribution (and to allow zone heating) than to increase heating capacity.

A conventional gas-heated water tank was also retained. This plus other sources, such as solar gain, appliances, lights, occupants, etc. provide a lesser amount of heat gain, not estimated in this study.

4.2 Ventilation

To reduce humidity and odour build-up caused by the tight seal, a ventilation system was provided. An air to air heat exchanger is used to exhaust stale air and recover its heat for preheating the incoming fresh air. The exchanger installed in the Laing residence is a "VanEE R-100", manufactured by Conservation Energy Systems and rated at 250 cfm.

5. AIR LEAKAGE TESTING

5.1 Air Infiltration

One characteristic of energy efficient homes is that uncontrolled air infiltration is minimized by the use of a continuous air/vapour barrier, by weatherstripping doors and windows, and by other sealing techniques (see Appendix B).

The blower door assembly test performed on the Laing home is one method used to measure the effectiveness of these techniques. The blower door test method induces and measures air leakage into houses at various pressure differentials between the indoor and outdoor air (see Appendix B for further details).

Data from these tests allow the relative degree of "tightness" to be estimated and compared to known standards for energy efficient housing. Two sets of calculated values which are useful for comparison are the number of air changes per hour (AC/hour) and the equivalent leakage area (ELA). The ELA, expressed in square meters, is the equivalent area of a single hole which would produce the same net leakage as the various cracks and other leakage sources found throughout the house.

5.2 Test Results

The retrofit was tested at the end of January, 1983, when only some minor interior finishing work remained to be done.

Air leakage tests were performed on the house according to standard practices at that time; i.e. with all doors and windows shut and all plumbing lines and drains sealed.

The air leakage characteristics are reported as the number of air changes per hour for pressure differentials of 10 and 50 Pascals. These differentials are equivalent, respectively, to 15 and 32 km/hr. winds blowing over the entire house envelope.

Table II

Air Leakage Test: Bruce Laing Residence

Air Change Rate @ 10 Pascals	=	0.61 AC/hr.
Air Change Rate @ 50 Pascals	=	1.64 AC/hr
Equivalent Leakage Area	=	0.04748 m^2

For comparison purposes, the number of air changes per hour at 50 Pascals and the ELA's for four different types of homes have been included in the following table:

Table III

Home Description	Air Change Rate @ 50 Pascals	ELA (m^2)
Pre-1945 construction	10.4	0.1078
1945-1960 construction	4.6	0.0709
1961-1980 construction	3.6	0.0621
Low Energy Home	1.5	0.0330
Bruce Laing Residence	1.64	0.0475

These results are based on air leakage tests performed on 176 homes in Saskatoon by the National Research Council of Canada.

The test results of the Laing house places it near the low energy home category.

6. POST-CONSTRUCTION MONITORING

Monitoring of the project will be achieved by comparing the energy consumptions for a full year before and after the retrofit comparison. The before phase includes the garage and original sunroom. The preliminary results given in Table IV compare the heat loads and consumptions for the first twelve months after the completion of the retrofit (January - December, 1983) to the equivalent months in 1981.

TABLE IV

Actual Natural Gas Consumption

Month	Fuel Consumption (MCF) 1981	1983	Degree Days 1981	1983
January	30	26	994	942
February	20	18	787	798
March	18	10	590	702
April	13	10	402	445
May	11	7	224	300
June	8	4	66	65
July	6	4	15	12
August	4	5	12	5
September	3	4	173	180
October	7	5	393	383
November	18	5	511	597
December	12	10	959	1,187
Total	150	108	4,762	5,616
Water heater Consumption	48	48		
Total Consumption for Space Heating	102	60		

An observed 4 mcf is consumed monthly for hot water heating.

With the above data, normalized annual heating loads can be estimated using the degree days for an average heating season for the Winnipeg area (5,932 degree days, based on 30 years of data collected by Environment Canada).

Normalized Annual Heating Load Estimates

Before retrofit:

$$\frac{102 \text{ MCF}}{4{,}762 \text{ D.D.}} \times \frac{5{,}932 \text{ D.D.}}{\text{yr.}} = 127 \text{ MCF/yr.}$$

After retrofit:

$$\frac{60 \text{ MCF}}{5{,}616 \text{ D.D.}} \times \frac{5{,}932 \text{ D.D.}}{\text{yr.}} = 63 \text{ MCF/yr}$$

Even with the useful living area being almost tripled, the gas consumption for a normal south-central Manitoba winter has been reduced by 50%, according to these estimates.

Using the lower heating value of natural gas, and assuming a typical 60% efficiency for the natural gas furnace installed in the Laing home, these values were converted into annual electrical heating loads (assuming 100% efficiency for electricity), as summarized in Table V.

In addition, unit annual heating loads were calculated for before and after the retrofit by dividing by the living areas (respectively 87.2 and 258 sq. m.) - Table V.

As previously discussed, electric heating was added to the second floor of the addition. According to the owner, the heaters ran for a total of 50 kW.h, for the period between February and May, 1983. An assumption is made that the electrical heating requirement for the whole heating season would be twice this amount or 100 kW.h, and this amount has been added in.

Table V

Annual Heating Loads

	Gas Heating Load	Equivalent Electrical Heating Load	Unit Area Electrical Heating Load
Before Retrofit	127 MCF/yr.	22,330 kW.h/yr.	256 kW.h/sq. m/yr.
After Retrofit	63 MCF/yr.	11,078 kW.h/yr.	43 kW.h/sq. m/yr.

The effectiveness of the energy conservation portion of the retrofit is shown by the comparison on a per unit area basis. The estimated unit area heat load was reduced by 83%.

7. ECONOMIC ANALYSIS

A rigorous economic analysis of the energy conserving measures is not possible because expansion of the heated living space was involved in addition to the retrofitting.

The owner estimated that $14,176 (out of a total of $31,400 for the expansion and retrofit) went toward energy related improvements. Based on the gas savings indicated by the preliminary results, the simple payback on the energy related improvements would be (assuming the current gas run-off rate of $5.02/MCF):

$$\frac{\text{Cost}}{\text{annual savings}} = \frac{\$14,176}{(127 - 63)\ \text{MCF/yr.} \times \$5.02/\text{MCF}} = 44 \text{ years}$$

However this simplistic approach does not take into account the increase in equity value and the intangible lifestyle benefits resulting from the expansion in living space.

Alternative estimates, which attempt to remove the effect of the expansion, are presented below. It is believed that these are more representative of the potential for energy savings from retrofitting older homes. However, since the estimates are based on results for a single home, and because lifestyles can vary greatly, generalization of specific results should be avoided.

a. This example estimates the energy savings that could have been achieved if the Laing home had been retrofitted but not expanded. The assumption is made that the same unit area gas heating load would have been attained in the smaller retrofitted house as has been in the expanded house.

Annual gas consumption for 87.2 sq. m. retrofitted house:

$$\frac{63 \text{ MCF/yr.}}{258 \text{ sq. m.}} \times 87.2 \text{ sq. m.} = 21 \text{ MCF/yr.}$$

The pre-retrofit gas consumption (measured) was 127 MCF/yr.

The owner estimated that the material and labour costs for the energy related retrofitting of the original sections of the house totalled $11,300. Based on this estimate, retrofitting of the original house would show a simple payback of

$$\frac{\$11,300}{(127-21) \text{ MCF/yr.} \times \$5.02/\text{MCF}} = 21.2 \text{ years}$$

b. The second example compares the savings that could be expected by upgrading an existing 258 sq. meter home (expanded size of project home) to the heat load level achieved in the project home (43 kW.h/sq. m./yr.)

Savings for an equivalent, electrically-heated house are also presented for comparison.

It was estimated that the average cost of an energy efficient retrofit for a 258 sq. meter house would be $15,000 (1983), based on experience with the project home and on other averages available to the Manitoba Department of Energy and Mines. This value was used for calculating the simple payback period in Table VI.

Table VI

Comparative Energy Consumptions and Savings
(258 square meter home)

	All Gas Heating Gas Consumption MCF/yr.	or	All Electric Heating Electrical Consumption kW.h/yr.
* Before retrofit (256 kW.h/sq.m/yr.)	375		66,048
After retrofit (43 kW.h/sq.m/yr.)	63		11,094
Fuel Savings	312		54,954
**Annual Dollar Savings	$1,566		$1,522
Simple Payback Period (Based on $15,000 capital cost)	9.6 years		9.8 years

* Calculated from electrical consumption figures, assuming lower heating value for natural gas and 60% efficiency for gas versus 100% efficiency for electricity.

** Based on $5.02/mcf for natural gas and on $.0277/kW.h for electricity.

These estimates serve to show that energy efficient retrofitting can be attractive, particularly for larger homes, where some economy of scale in the material and labour costs may apply. If structural renovation of an older home is already planned, the inclusion of energy efficient construction techniques and materials should be considered as worthwhile investments.

8. SUMMARY OF OBSERVATIONS AND RECOMMENDATIONS

8.1 No major problems were encountered during the construction. The owner/builder experienced some difficulty with sealing the joint between the house and the garage.

8.2 As a result of careful installation of the air/vapour barrier and extensive caulking, air infiltration was reduced to low levels. Air leakage testing showed a leakage rate of 1.64 air changes per hour at a pressure differential of 50 Pascals, which compares with other low energy homes.

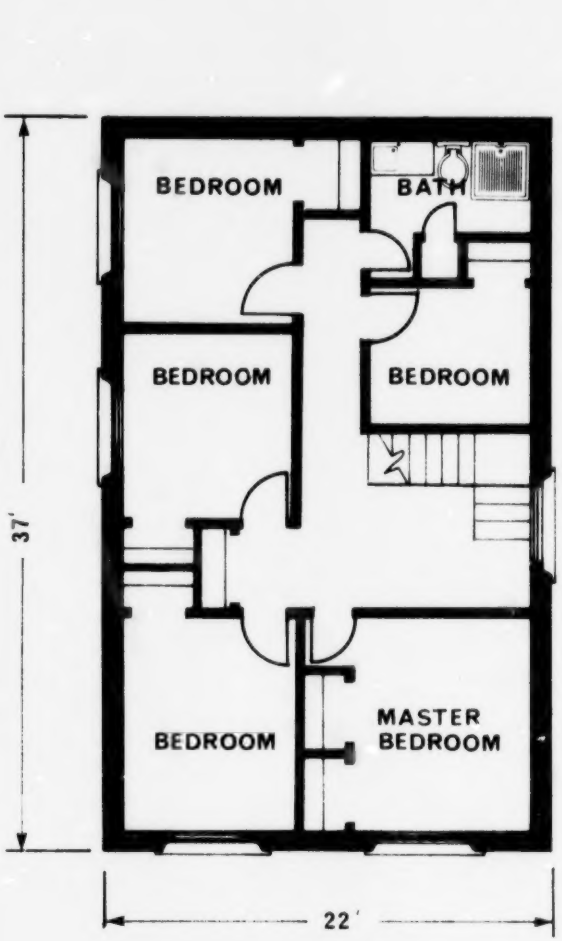
8.3 The normalized energy consumption was reduced by 50% from the pre-retrofit levels, even though the living area was almost tripled. As a better indication of the increased energy efficiency, the unit area heating load was reduced by 83%, from 256 kW.h/sq. m./yr. to 43 kW.h/sq. m/yr.

8.4 While economic analysis of the energy saving retrofit was complicated by the simultaneous expansion of living space, estimates were made to compensate for this change. According to the estimates, simple payback periods would range between 10 and 21 years depending on the size and pre-retrofit condition of the home.

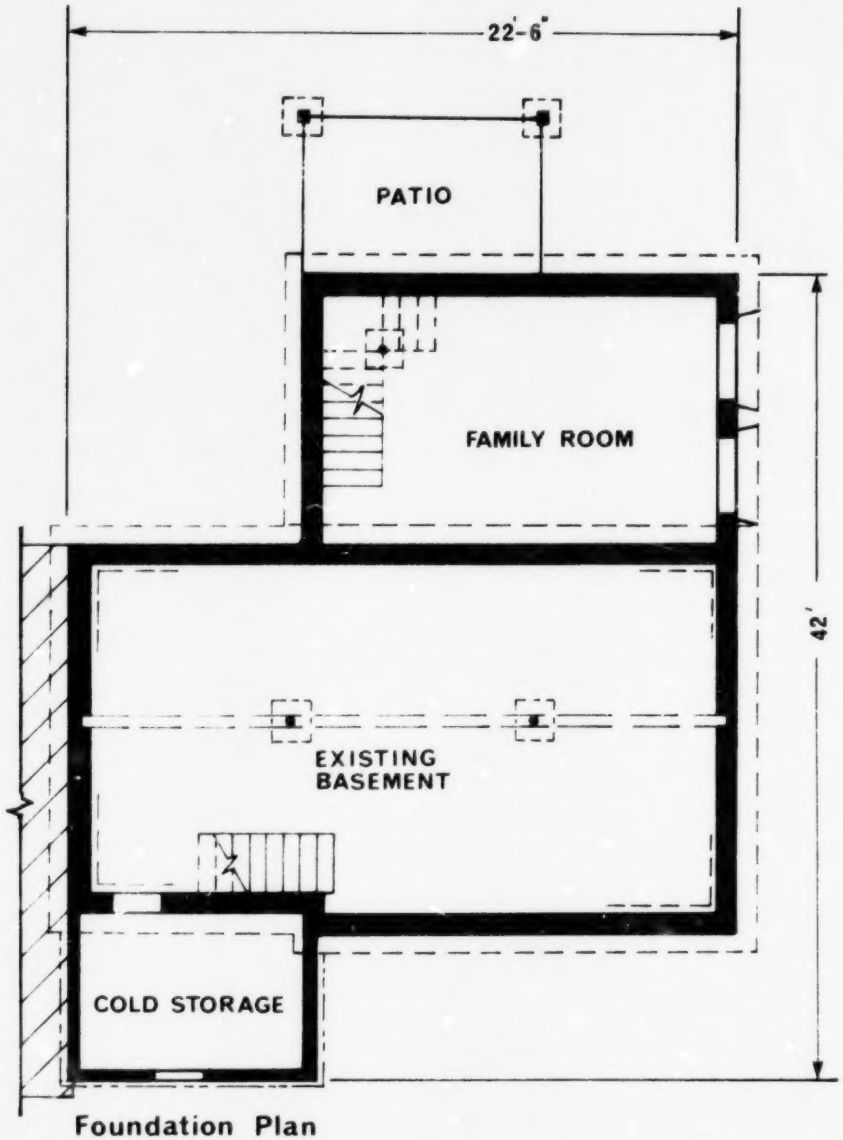
8.5 This project points to the advantages of retrofitting an older home rather than replacing it. In addition to lower fuel bills and increased comfort, the market value of the project home has increased substantially as a result of the retrofit. An energy efficient retrofit can be especially justified if the house requires renovations such as a new roof or exterior.

APPENDIX A

FLOOR PLANS AND WALL CROSS SECTION



Upper Level



Foundation Plan

LAING HOUSE

EXISTING WALLS

FIGURE A1

FIGURE A2

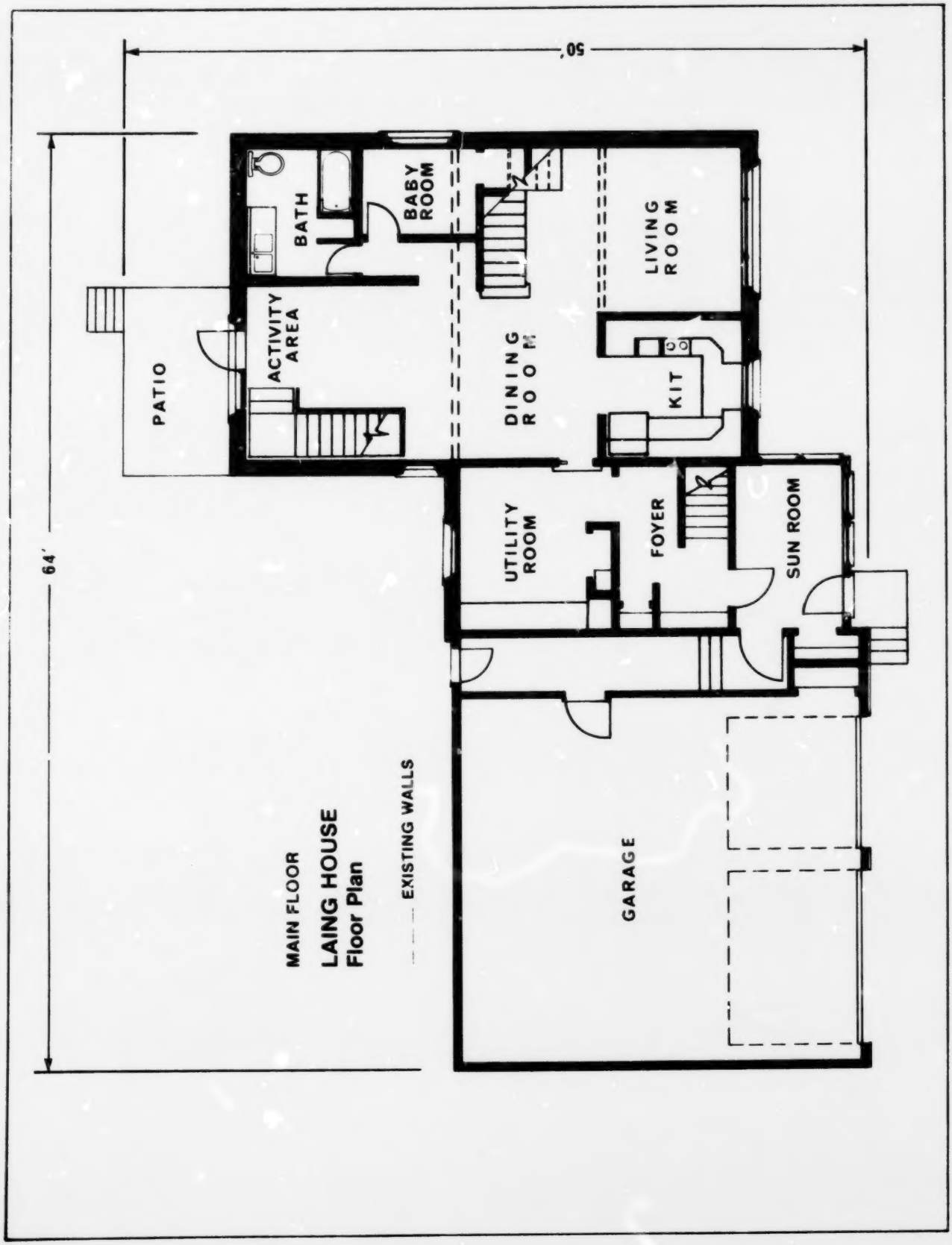
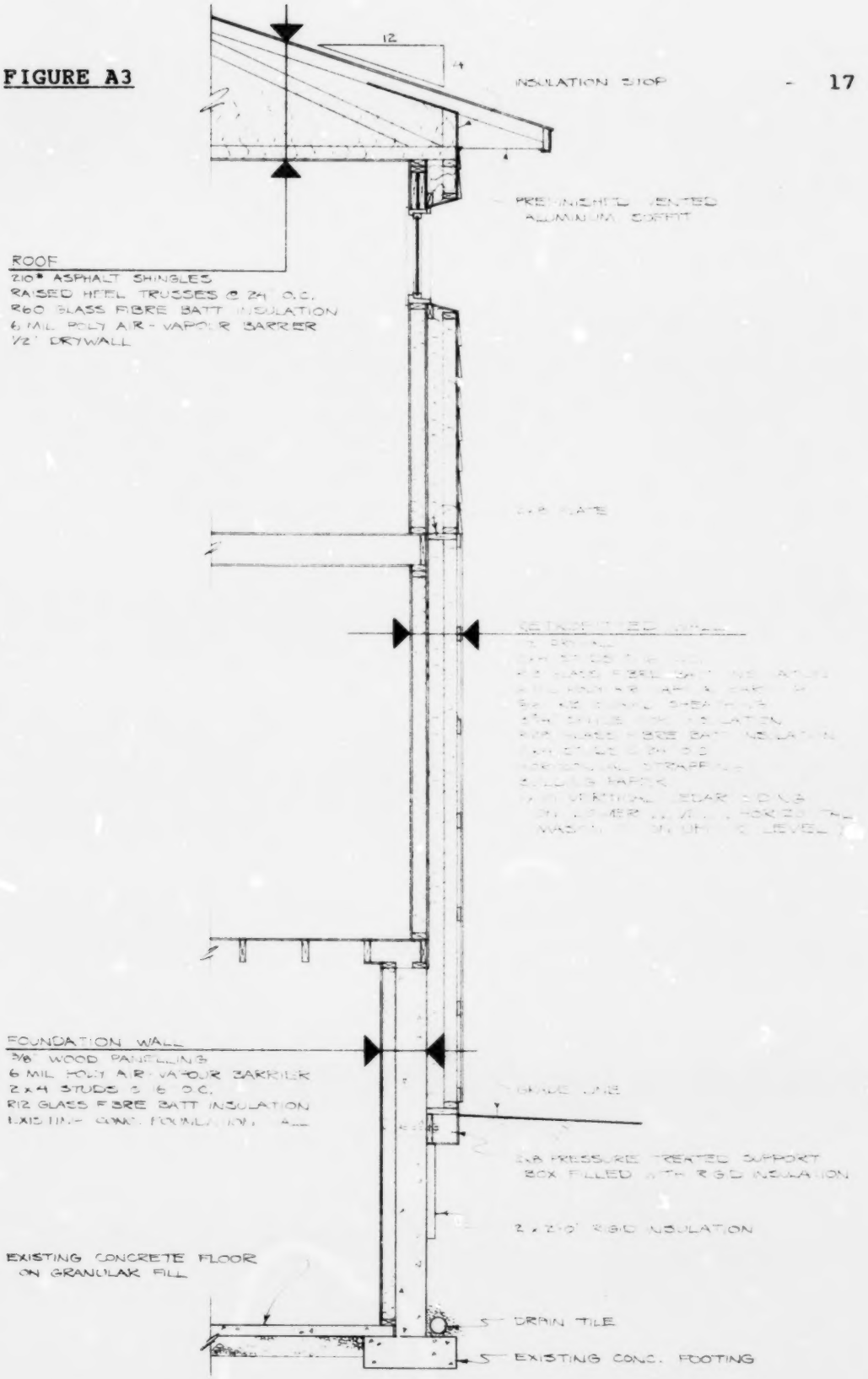
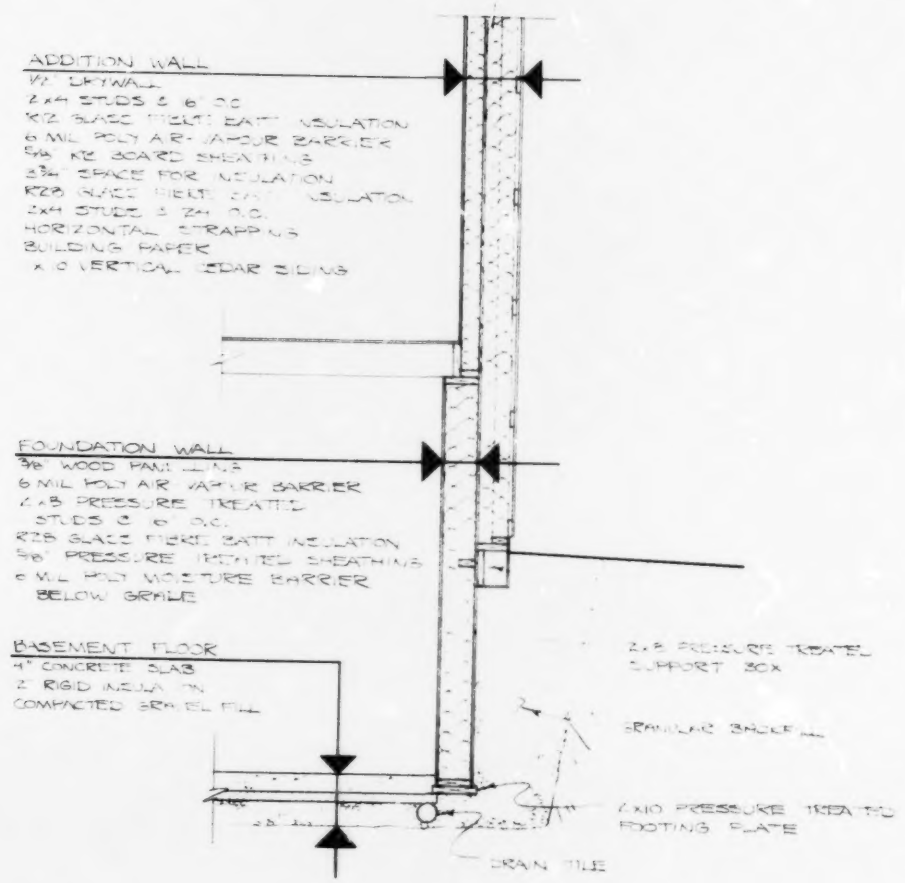

50'
64'
PATIO
ACTIVITY AREA
BATH
BABY ROOM
DINING ROOM
LIVING ROOM
KIT
UTILITY ROOM
FOYER
SUN ROOM
GARAGE
MAIN FLOOR
LAING HOUSE
Floor Plan
EXISTING WALLS

FIGURE A3


12
4
INSULATION STOP
PREFINISHED VENTED ALUMINUM SOFFIT
ROOF
210# ASPHALT SHINGLES
RAISED HEEL TRUSSES @ 24" O.C.
R60 GLASS FIBRE BATT INSULATION
6 MIL POLY AIR - VAPOUR BARRIER
1/2" DRYWALL
FOUNDATION WALL
3/8" WOOD PANELLING
6 MIL POLY AIR VAPOUR BARRIER
2x4 STUDS @ 16" O.C.
R12 GLASS FIBRE BATT INSULATION
2x8 PRESSURE TREATED SUPPORT BOX FILLED WITH R5.0 INSULATION
2 x 2'-0" RIGID INSULATION
EXISTING CONCRETE FLOOR ON GRANULAR FILL
5" DRAIN TILE
5" EXISTING CONC. FOOTING

RETROFITTED WALL AND FOUNDATION CROSS SECTION
NOT TO SCALE

FIGURE A4



ADDITION WALL AND FOUNDATION CROSS SECTION
NOT TO SCALE

APPENDIX B

AIR LEAKAGE AND BLOWER DOOR DESCRIPTION

AIR INFILTRATION

IMPORTANCE OF AIR INFILTRATION

All houses experience uncontrolled air infiltration to varying degrees. This provides fresh air for breathing, odor and moisture control, as well as supplying combustion air for appliances such as gas or oil furnaces. Unfortunately, this outdoor air must be heated to room temperature and thus constitutes an additional heating load for the furnace to meet. The magnitude of this load is higher than most people realize. In fact, air infiltration is responsible for 15% to 40% of the total heating bill in most Manitoba homes.

CAUSES AND SOURCES OF AIR INFILTRATION

Air infiltration is produced by three forces; wind, stack effect and mechanical ventilation. Wind action puts the windward side or half of a house under a positive pressure differential (i.e. outdoor air pressure is greater than indoor) causing a net inward flow of air, and the leeward side under a negative pressure differential, creating a net outward air flow. Stack effect is produced by the indoor to outdoor temperature differential and typically creates a net inflow over the bottom half of the house and an outflow over the top half. Mechanical ventilation accounts for the air admitted to the house to replace air exhausted through kitchen or bathroom fans.

The primary sources of air infiltration (i.e. where the air actually enters or leaves the house) are listed below in their order of importance:

a) around top and bottom sill plates,

b) past electrical outlets on exterior walls,

c) through breaks in the ceiling vapor barriers caused by ceiling light fixtures, attic hatches, interior partitions, plumbing stacks, etc.

d) through leaky doors and windows,

e) other miscellaneous sources such as chimneys, fireplaces, floor drains, etc.

THE BLOWER DOOR ASSEMBLY

COMPONENTS

The blower door assembly consists of four major components: a collapsible door which fits into the door opening of the test house, an electric blower with speed control to exhaust air from the structure, a bell mouth nozzle to measure the quantity of air being exhausted and a house pressure manometer to determine the indoor to outdoor pressure differential created by the blower. These are illustrated in Figure B1.

Collapsible D - The door is constructed of plywood and is composed of three hinged sections. When fully extended, its dimensions are 81 cm x 203 cm (32" x 80") - the standard residential door size. The unit is held firmly in place in the opening by four wooden brackets so that a tight seal exists between the door and the opening. When fully collapsed, the unit can be easily transported by one man.

Blower - The blower is permanently bolted to the centre of the collapsible door and has a capacity of approximately 556 l/s (1200 cfm) which is adjustable with the speed controller. The unit exhausts air from the house through the nozzle.

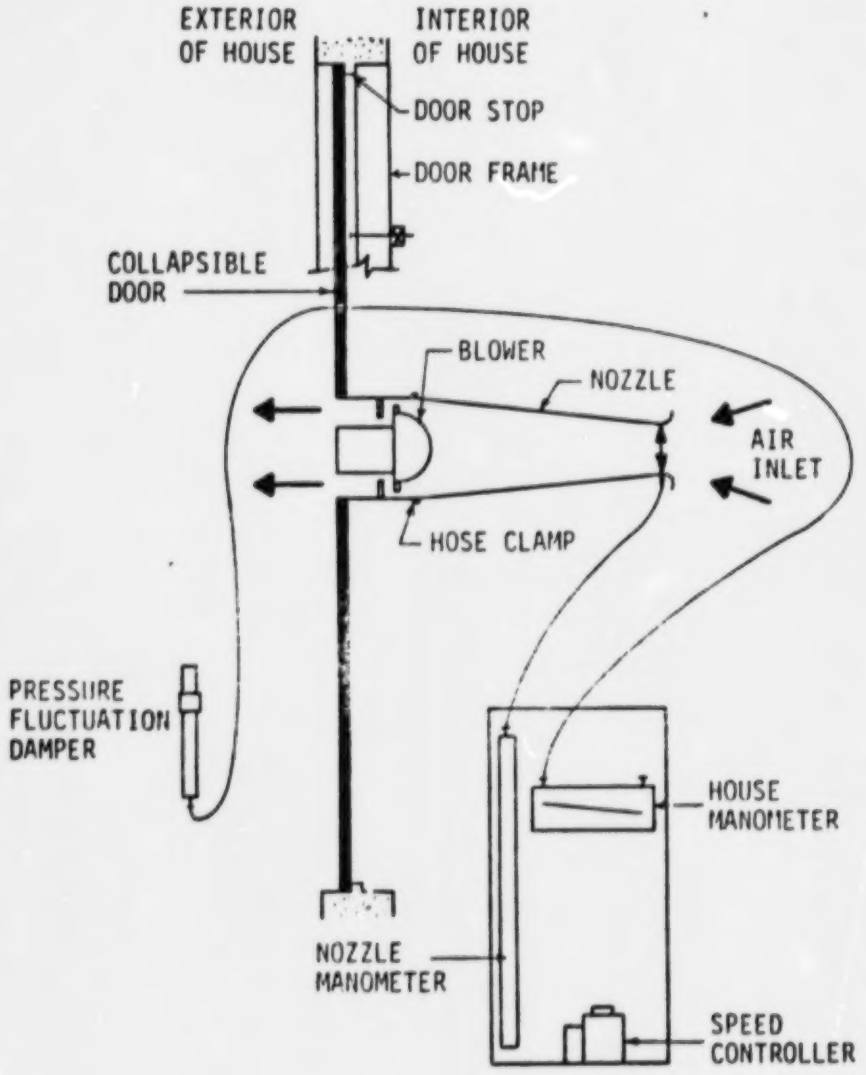
Nozzle - The bell mouth nozzle is constructed of fibreglass with metal flow straighteners. It is affixed to the blower before the test by a single clamp. The quantity of air being exhausted through the blower is accurately determined by measuring the pressure drop at the throat section of the nozzle. Pressure taps at the nozzle throat are hooked up to the low pressure side of a vertical manometer by a single flexible tube. The high pressure side of the manometer is left open to the atmosphere. The nozzle manometer is located in a wooden carrying case with the house pressure manometer.

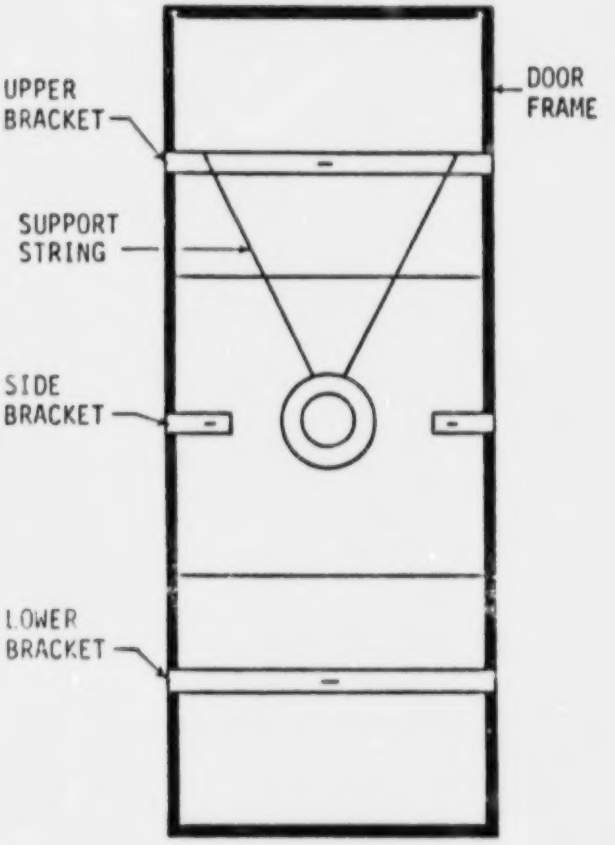
House Pressure Manometer - This measures the actual indoor to outdoor pressure difference created by the exhaust fan. The indoor tap is left open to room air and the outdoor tap is connected to a pressure fluctuation damper through a 6 m (20') flexible tube. The damper is placed in the yard at a location where the effects of wind turbulence are minimized.

OPERATION

The use of the blower door assembly is straightforward; an entire test from arrival at the house to departure can be performed by one man in one and one-half hours.

Normally, two tests are conducted on each house. The first is done with the chimney and other vents open to stimulate the actual operating condition of the house and the second with them closed to evaluate the integrity of the wall, ceiling and floor vapor barriers. The first test may not prove necessary if the investigator is only concerned with studying how uncontrolled leakage through the vapour barrier can be reduced.





INTERIOR VIEW

BLOWER DOOR ASSEMBLY GENERAL ARRANGEMENT

DEFINITIONS

A. House Pressure

This is the envelope pressure produced by the blower door assembly and is measured in Pascals.

B. Nozzle Pressure

This is the pressure created by the air flow at the throat of the nozzle, and is measured in Pascals.

C. Air Flow Rate

The nozzle is a carfully calibrated, long radius ASME nozzle with known characteristics. The relationship between the nozzle pressure and air flow rate has been determined in the laboratory and the nozzle pressure is then used to calculate the corresponding air flow rate.

D. Correlation Coefficient (r)

In order to determine the accuracy of the pressurization data, some indication of how well the points 'fit' on a straight line must be included. The determination of the correlation coefficient is a complicated but very accurate means of ensuring an acceptable 'fit'. If the value of r is less than 0.9800 the leakage test must be repeated.

E. Air Change Rate

The air change rate is the number of times that the entire air volume within the structure changes each hour at a specific pressure differential. The pressure differential of 50 Pascals is selected to conform with the reference pressure used internationally to report air change rates. This value is determined by dividing the air flow rate per hour at a 50 Pascal pressure differential by the heated volume of the structure.

APPENDIX C

PHOTOGRAPHS

Early Retrofit

During the Retrofit

Raised Heel Truss
and Continuous
Vapor Barrier

POOR

QUALITY

ORIGINAL